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WIND-TUNNEL INVESTIGATION OF PROFILE DRAG AND LIFT OF AN INTERMEDIATE WING SECTION OF THE XP-51 AIRPLANE WITH BEVELED TRAILING-EDGE AND CONTOUR AILERONS

By Frank T. Abbott, Jr. and William J. Underwood

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

WIND-TUNNEL INVESTIGATION OF PROFILE DRAG AND LIFT OF AN INTERMEDIATE WING SECTION OF THE XP-51 AIRPLANE WITH BEVELED TRAILING-EDGE AND CONTOUR AILERONS

By Frank T. Abbott, Jr. and William J. Underwood

INTRODUCTION

The results of flight investigations showed that a beveled trailing-edge aileron gave as low or a lower profile drag than a contour aileron. As this was contrary to the general expectation, it was felt desirable to conduct a wind-tunnel investigation of a scale model of the wing section used in flight. Section profile drag and section lift at flight Reynolds numbers were to be obtained with the two types of ailerons.

Section profile drag and lift coefficients at Reynolds numbers of approximately 6,000,000, 9,000,000, and 13,000,000 are presented herein from the tests in the NACA two-dimensional low-turbulence pressure tunnel.

MODEL

A scale model having a wing chord c of 36 inches was made to correspond to an intermediate section over the aileron portion of the wing 16 inches outboard from the inboard end of the right aileron of the XP-51 airplane. This was the same section used in measuring profile drag in flight (reference 1). The ordinates of the section (table 1) were measured from the actual airplane wing. The scale model, which was made of laminated mahogany, was faired according to the measured ordinates with the exception of several slightly unfair ordinates on the upper and lower surfaces in the vicinity of the leading edge, which were neglected in fairing the airfoil contour. This unfairness of the measured ordinates was probably due to the actual airplane wing being slightly unfair at the front spar. A bump was present on the lower surface of the model at the aileron hinge simulating the contour of the aileron projecting below the lower surface at the hinge line. This bump was present in the plain airfoil configuration (fig. 1) as well as the two aileron configurations (figs. 2 and 3). The model was made in two parts with a single front part which assembled with one of three rear parts to form the plane airfoil section (fig. 1) or an airfoil section with either the 0.189c beveled trailing-edge aileron (fig. 2) or the 0.187c contour-shaped aileron (fig. 3). The internal shapes in the aileron balance chamber were scaled from the actual section tested in flight. Both ailerons were hinged at 0.813c, which resulted in a wing chord section c of about 36.1 inches for the beveled trailing-edge configuration. The beveled trailing-edge aileron configuration was tested unsealed. The contour aileron configuration was tested both unsealed and sealed.

METHOD

Lift and drag measurements of the model were made by methods described in reference 2. The profile-drag and lift coefficients for all configurations were based on a nominal wing chord c of 36 inches.[1]

The contour aileron was sealed by plugging the aileron curtain gaps with modeling clay. The discontinuity at the gaps was not faired out, as shown in the photograph of figure 3.

[1]After this report was issued in its original form, certain refinements were made in the method of computing lift coefficients. All lift coefficients given in this report should therefore be corrected by the following equation:

$$c_l(\text{corrected}) = 0.966c_l + 0.026c_{l_b}$$

where c_l is section lift coefficient presented in this report and c_{l_b} is given in the following table:

Aileron deflection δ_a (deg)	c_{l_b}
0	0.1
2	.2
5	.3
10	.5
18	.7
-2	.05
-5	-.1
-10	-.3
-18	-.5

RESULTS AND DISCUSSION

The results of the tests of the three configurations are presented in figures 4 to 12. Comparison curves of the configurations are given in figures 13 and 14. Aileron effectiveness $\frac{\Delta\alpha}{\Delta\delta}$ of the two aileron configurations is given in table II.

The comparison of section lift characteristics at a Reynolds number of 13,000,000, given in figure 13, shows that the plain airfoil had the highest slope with a $\left(\frac{dc_l}{d\alpha}\right)_{\alpha=0}$ of 0.115; followed by the sealed contour aileron configuration with a $\left(\frac{dc_l}{d\alpha}\right)_{\alpha=0}$ of 0.114; by the unsealed contour aileron configuration with a $\left(\frac{dc_l}{d\alpha}\right)_{\alpha=0}$ of 0.112; and last by the beveled trailing-edge aileron configuration with a $\left(\frac{dc_l}{d\alpha}\right)_{\alpha=0}$ of 0.105. A maximum section lift coefficient of 1.75 for the plain airfoil section is very good. The aileron configurations with the aileron neutral show a loss in maximum lift. Sealing the gaps of the contour aileron had little effect on either the slope of the lift curve or the maximum lift coefficient.

The aileron effectiveness, presented in table II as the effective change in angle of attack per unit change in aileron angle (denoted by $\Delta\alpha/\Delta\delta$), shows that the contour aileron, either sealed or unsealed, has an appreciably

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higher $\Delta\alpha/\Delta\delta$ than the beveled trailing-edge aileron. Sealing the aileron gaps of the contour aileron resulted in a small improvement in effectiveness.

Although no study of hinge moments was included in the present investigation, it appears (reference 3) that this loss in effectiveness of the beveled trailing-edge aileron can be more than counteracted by using larger aileron deflections than would be obtainable with the unbalanced contour aileron with permissible stick forces. The final effectiveness of the beveled trailing-edge aileron would appear, however, to be less than that of a properly balanced contour aileron.

The comparison of the drag polars, with the aileron neutral, given in figure 14, shows that the section profile drag coefficient $c_{d_{o_{min}}}$ is lowest for the plain airfoil section. The contour aileron configuration, sealed and unsealed, shows a slightly higher c_{d_o} than the plain airfoil section. In the sealed condition the contour aileron shows the same profile drag as the plain airfoil section outside the low-drag range. The beveled trailing-edge aileron configuration shows an increase in c_{d_o} throughout the test range. In the low-drag range the beveled trailing-edge aileron configuration shows an increase in the profile drag $\left(c_{d_{o_{min}}}\right)$ of about 0.0003 over the plain airfoil section drag and possibly 0.0002 over the contour aileron configuration section drag.

CONCLUDING REMARKS

The section profile-drag coefficient of the beveled trailing-edge aileron configuration was slightly higher than for the contour aileron configuration.

The section aileron effectiveness per unit aileron deflection of the beveled trailing-edge aileron unsealed was approximately 80 percent of the effectiveness of the contour aileron, unsealed.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 27, 1943.

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REFERENCES

1. Zalovcik, John A.: A Profile-Drag Investigation in Flight on an Experimental Fighter-Type Airplane - The North American XP-51 (A. C. No. 41-38). NACA A.C.R., Nov. 1942.

2. Abbott, Ira. H., von Doenhoff, Albert, E., and Stivers, Louis S., Jr.: Summary of Airfoil Data. NACA ACR No. L5C05, 1945.

3. White, M. D., and Hoover, Herbert H.: Flight Tests of Modifications to Improve the Aileron Control Characteristics of a North American XP-51 Airplane. (A. C. No. 41-38). NACA MR, June 20, 1942.

TABLE I

ORDINATES OF AIRFOIL SECTION AND AILERONS OF INTERMEDIATE WING SECTION OF XP-51 AIRPLANE

Plain wing section			Wing section with contour aileron			Wing section with beveled trailing-edge aileron		
x/c	y_U/c	y_L/c	x/c	y_U/c	y_L/c	x/c	y_U/c	y_L/c
0	0	0	0	Same as plain wing section		0	Same as plain wing section	
.0125	.0184	-.0134	.805			.805		
.025	.0267	-.0181	.809	.0295	-.0146	.810	.0302	-.0162
.05	.0368	-.0249	.8125	.0302	-.0156	.816	.0308	-.0166
.075	.0438	-.0304	.815	.0302	-.0154	.820	.0302	-.0165
.10	.0500	-.0349	.8175	.0298	-.0151	.84	.0281	-.0159
.15	.0598	-.0412	.82	.0292	-.0143	.88	.0238	-.0148
.20	.0664	-.0464	.83	.0270	-.0133	.92	.0196	-.0136
.25	.0717	-.0506	.85	.0228	-.0113	.942	.0166	-.0124
.30	.0763	-.0546	.90	.0133	-.0066	.95	.0146	-.0109
.35	.0787	-.0550	.95	.0056	-.0024	.965	.0109	-.0078
.40	.0793	-.0552	.998	.0011	-.0011	.98	.0067	-.0051
.45	.0790	-.0545	1.000	0	0	1.00	.0010	-.0010
.50	.0769	-.0530				1.002	0	0
.60	.0675	-.0447						
.70	.0520	-.0319						
.80	.0338	-.0168						
.805	.0326	-.0163						
.8125		-.0156						
.815		-.0154						
.8175		-.0151						
.82		-.0143						
.85	.0228	-.0113						
.90	.0133	-.0066						
.95	.0056	-.0024						
.998	.0011	-.0011						
1.000	0	0						

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TABLE II

CHANGE IN EFFECTIVE ANGLE OF ATTACK PER UNIT CHANGE OF AILERON ANGLE OF A SCALE MODEL OF THE INTERMEDIATE WING SECTION OF THE XP-51 AIRPLANE

(For aileron deflections, δ_a, $\leq \pm 18^\circ$; R, 13×10^6 approx.)

Aileron configuration	$\left(\frac{\Delta\alpha}{\Delta\delta}\right)_{c_l = 0}$	$\left(\frac{\Delta\alpha}{\Delta\delta}\right)_{c_l = .7}$
Beveled trailing-edge	0.37	0.36
Contour type, unsealed	.46	.44
Contour type, sealed	.48	.46

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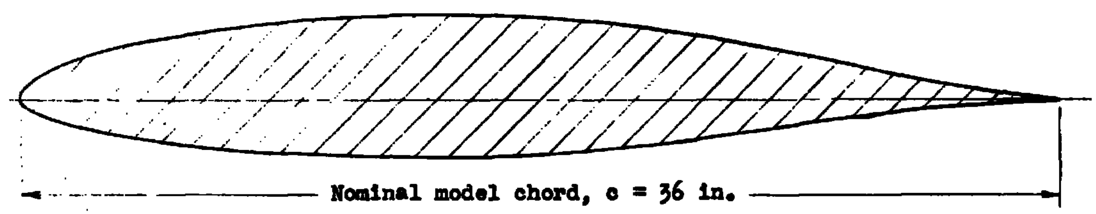

Figure 1.- Configuration of a scale model of the intermediate wing section of the XP-51 airplane.

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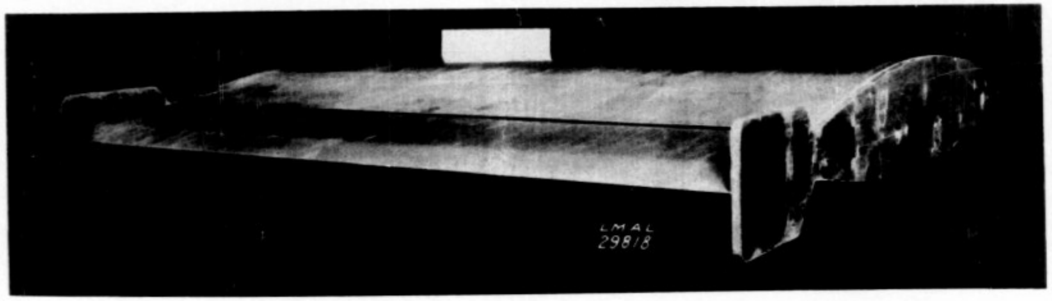

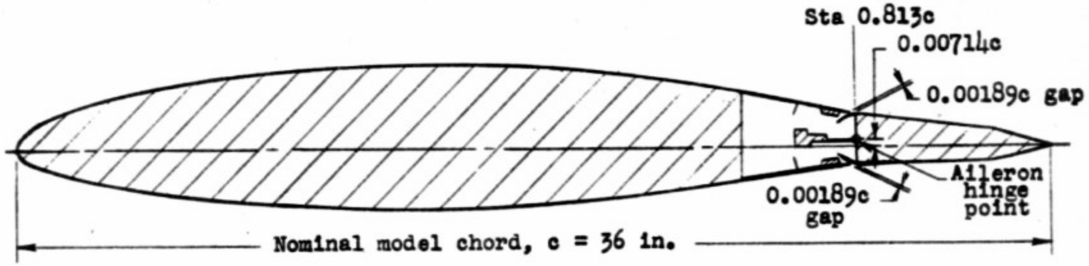

Figure 2.-. Configuration of a scale model of the intermediate wing section with 0.189c beveled trailing-edge aileron of the XP-51 airplane. (Photograph shows model in unsealed condition.)

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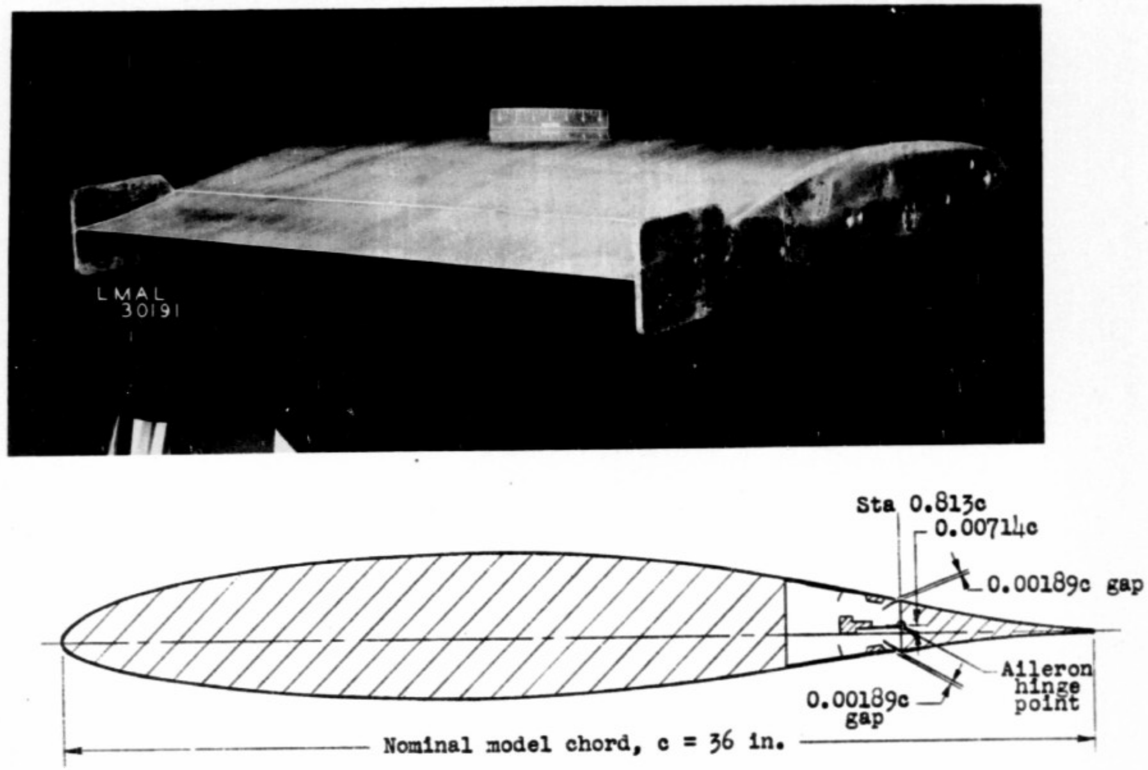

Figure 3.- Configuration of a scale model of the intermediate wing section with 0.187c contour-type aileron of the XP-51 airplane. (Photograph shows model in sealed condition.)

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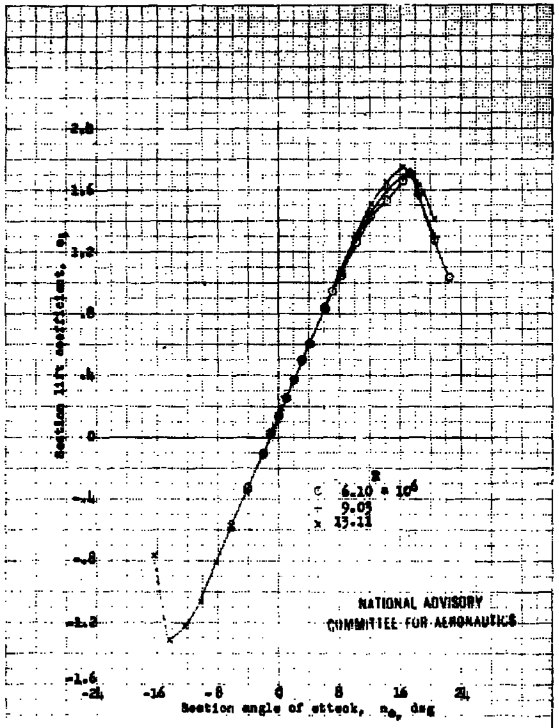

Figure 4.- Section lift characteristics of a scale model of the intermediate wing section of the XP-51 airplane.

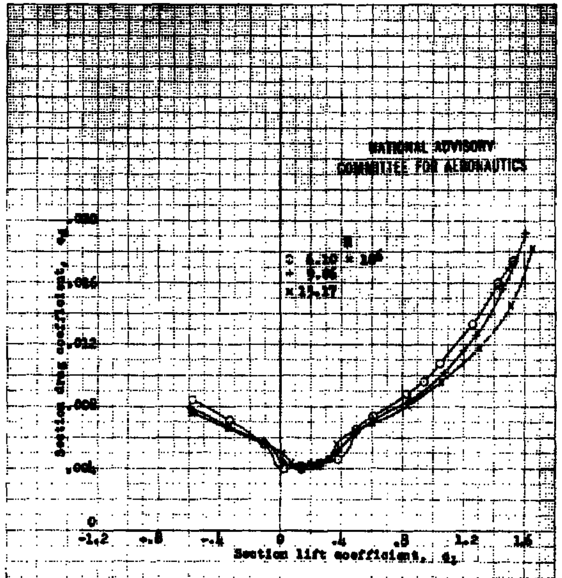

Figure 5.- Section drag characteristics of a scale model of the intermediate wing section of the XP-51 airplane.

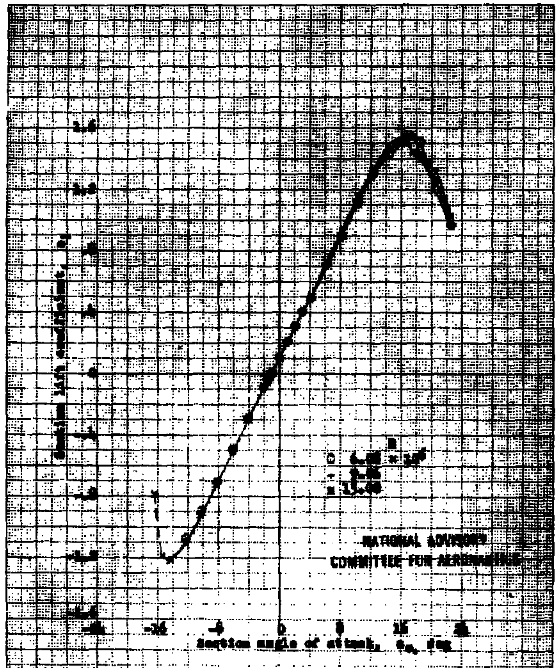

Figure 6.- Section lift characteristics of a scale model of the intermediate wing section with 0.189c beveled trailing-edge aileron, unsealed, of the XP-51 airplane, δ_a, 0°.

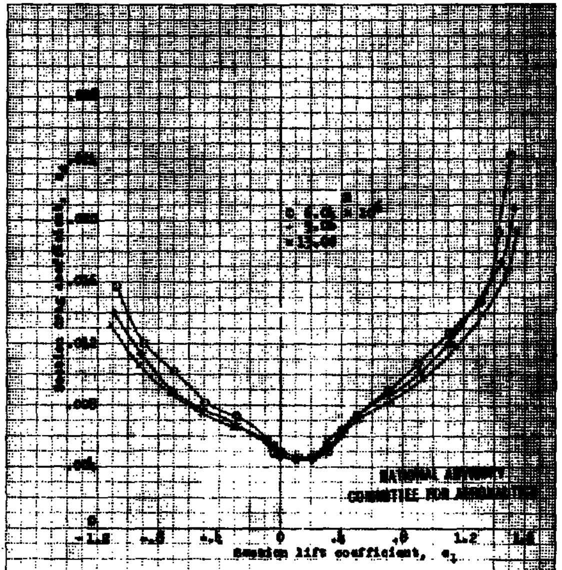

Figure 7.- Section drag characteristics of a scale model of the intermediate wing section with 0.189c beveled trailing-edge aileron, unsealed, of the XP-51 airplane. δ_a, 0°.

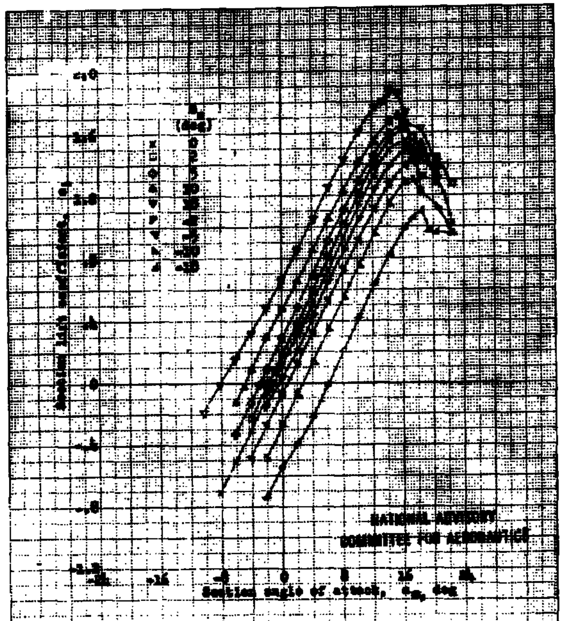

Figure 8.- Section lift characteristics of a scale model of the intermediate wing section with 0.189c beveled trailing-edge aileron, unsealed, of the XP-51 airplane. R, 13 × 10^6 (approx.).

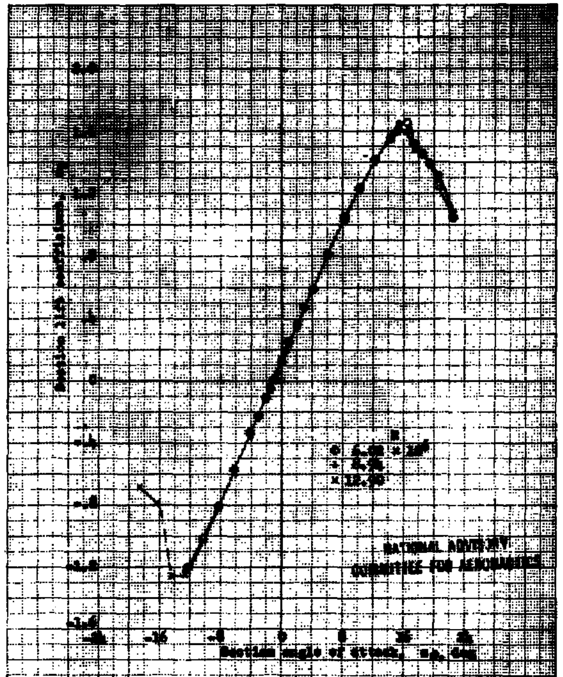

Figure 9.- Section lift characteristics of a scale model of the intermediate wing section with 0.187c external-type aileron, unsealed, of the XP-51 airplane. δ_a, 0°.

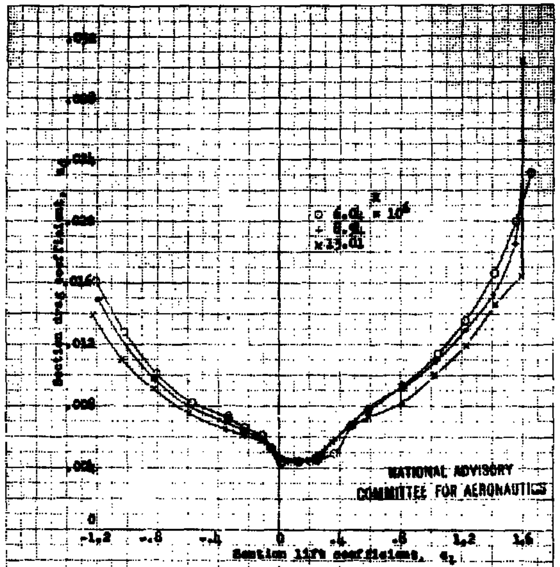

Figure 10.- Section drag characteristics of a scale model of the intermediate wing section with 0.157c contour-type aileron, unsealed, of the XP-51 airplane. δ_a, 0°.

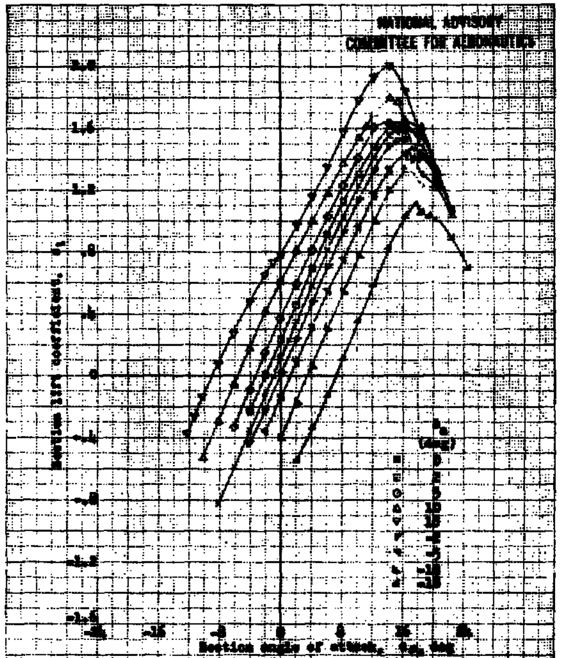

Figure 11.- Section lift characteristics of a scale model of the intermediate wing section with 0.157c contour-type aileron, unsealed, of the XP-51 airplane. R, 15 × 10^6 (approx.).

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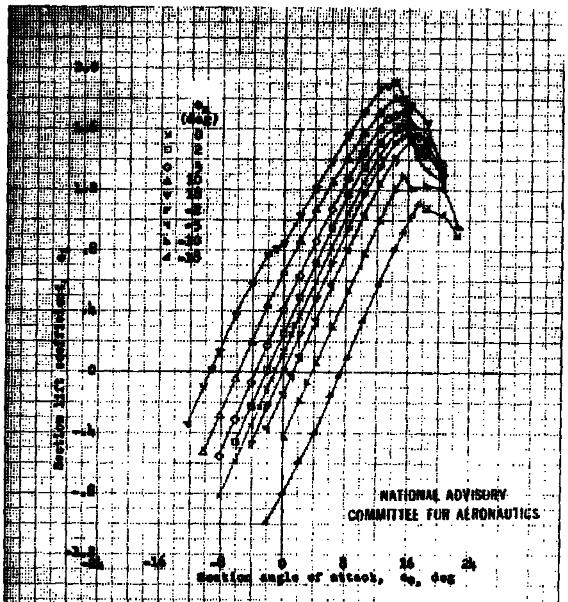

Figure 12.- Section lift characteristics of a scale model of the intermediate wing section with 0.187c contour-type aileron, sealed, of the XP-51 airplane. R, 12 x 10^6 (approx.).

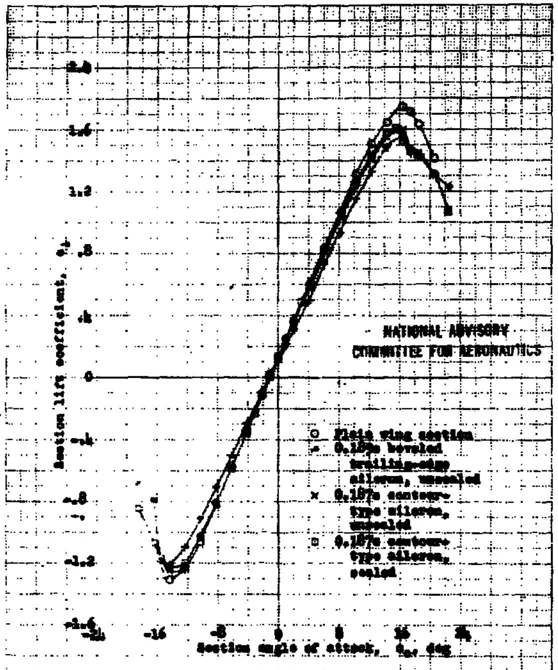

Figure 13.- Comparison of section lift characteristics of a scale model of the intermediate wing section with various configurations of the XP-51 airplane. δ_a, 0°; R, 15 × 10⁶ (approx.).

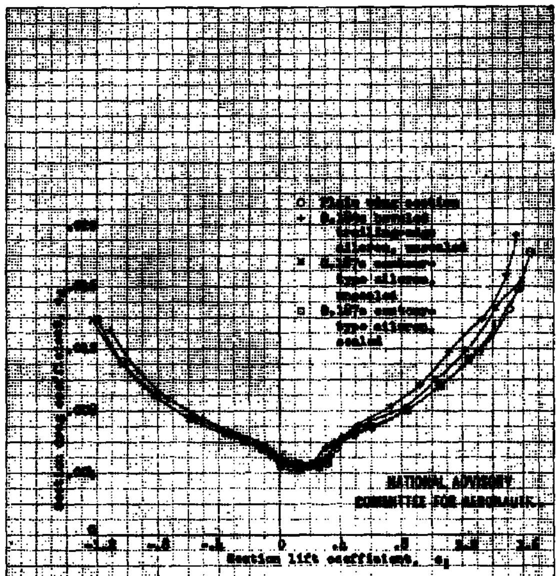

Figure 14.- Comparison of section drag characteristics of a scale model of the intermediate wing section with various configurations of the XP-51 airplane. δ_a, 0°; R, 15 × 10⁶ (approx.).

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ABSTRACT:

Section profile drag and section lift at flight Reynolds Numbers were obtained with two types of ailerons tested to verify questionable flight investigation results. Conclusions show that the profile-drag coefficient of the beveled trailing-edge aileron configuration was slightly higher than for the contour aileron configuration. Section aileron effectiveness per unit aileron deflection of the beveled trailing-edge aileron was approximately 80% of the effectiveness of the contour aileron.

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